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published in
International Journal of Sports Physiology and Performance
2013

DOI (link to publisher)
10.1123/ijspp.8.3.307

document version
Publisher's PDF, also known as Version of record

International Journal of Sports Physiology and Performance, 2013, 8, 307-311

INTERNATIONAL JOURNAL OF
SPORTS PHYSIOLOGY
AND PERFORMANCE
www.IJSPP-Journal.com
ORIGINAL INVESTIGATION

Effect of Warm-Up and Precooling on Pacing During a 15-km Cycling Time Trial in the Heat

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Purpose: The best way to apply precooling for endurance exercise in the heat is still unclear. The authors analyzed the effect of different preparation regimens on pacing during a 15-km cycling time trial in the heat. ***Methods:*** Ten male subjects completed four 15-km time trials (30°C), preceded by different preparation regimes: 10 min cycling (WARM-UP), 30 min scalp cooling of which 10 min was cycling (SC+WARM-UP), ice-slurry ingestion (ICE), and ice slurry ingestion + 30 min scalp cooling (SC+ICE). ***Results:*** No differences were observed in finish time and mean power output, although power output was lower for WARM-UP than for SC+ICE during km 13–14 (17 ± 16 and 19 ± 14 W, respectively) and for ICE during km 13 (16 ± 16 W). Rectal temperature at the start of the time trial was lower for both ICE conditions (~36.7°C) than both WARM-UP conditions (~37.1°C) and remained lower during the first part of the trial. Skin temperature and thermal sensation were lower at the start for SC+ICE. ***Conclusions:*** The preparation regimen providing the lowest body-heat content and sensation of coolness at the start (SC+ICE) was most beneficial for pacing during the latter stages of the time trial, although overall performance did not differ.

Keywords: thermoregulation, power output, ice slurry, scalp cooling

Athletes generally perform active warm-up to prepare for an upcoming event. This is proposed to induce beneficial physiological responses.[1–4] However, warm-up also elevates the core temperature, causing fatigue and reduced endurance performance in the heat.[5–7] Precooling may attenuate this detrimental effect by increasing the heat-storage capacity of the body and is therefore suggested to be a more beneficial preparation regimen than warming up.[6]

Ice-slurry ingestion appears to be an effective and practical method to precool the body core.[8–10] The lower core temperature resulting from ice-slurry ingestion may prevent or delay the reduction in central neural drive that leads to performance decrements in the heat.[11]

Next to cooling the core, cooling the skin could also affect performance.[8,12] Recently, a new convective cooling method for reducing chemotherapy-induced hair loss has become available, using glycol-perfused caps to cool the skin of the scalp. Possible mechanisms include a positive effect on the perception of coolness, motivation to continue exercise, and reduction of cardiovascular and thermoregulatory demands. The scalp may be a suitable cooling area, as it is easily accessible[13] and close to the thermosensitive region of the face. In addition, possible brain cooling may help maintain the central neural drive during exercise in the heat.[14] Both the sensation of coolness and possible brain cooling might translate into an improvement in self-paced exercise performance mediated by the rating of perceived exertion (RPE), even when core temperatures are well below critical values associated with fatigue.[15]

Although both warm-up and precooling have proved to be beneficial for endurance-exercise performance, it remains unclear which preparation regimen should be preferred for relatively short self-paced endurance exercise in the heat. Furthermore, the additive effect of scalp cooling when the core is cooled or heated remains unclear. Therefore, the main goal of this study was to investigate the effect of different preparation regimens (involving warm-up, ice-slurry ingestion, and scalp cooling) on pacing and performance during a 15-km cycling time trial (TT) in the heat.

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Methods

Subjects

Ten healthy and physically active male recreational cyclists (age 24 ± 5 y, height 187 ± 7 cm, weight 77 ± 6 kg) familiar with cycle-ergometer testing participated in this study. The study was approved by the ethics committee of TNO, The Netherlands.

Overview

Subjects visited the laboratory 5 times. On the first visit they were familiarized with the experimental setup and distance of the TT. The 4 following sessions involved the 15-km TT in the heat preceded by 1 of the different preparation regimens: active warm-up of 10 minutes of cycling (WARM-UP), scalp cooling + active warm-up of 10 minutes of cycling (SC+WARM-UP), ice-slurry ingestion (ICE), or scalp cooling + ice-slurry ingestion (SC+ICE).

Interventions

In the precooling trials (ICE and SC+ICE), a decrease in core temperature was created by ingesting 2 g/kg body mass (BM) ice slurry within 5 minutes. Syrup (containing ~6 g carbohydrates) was added for flavor. This period was followed by 15 minutes of rest. In the prewarming trials (WARM-UP and SC+WARM-UP), the subjects cycled at a moderate power of 2 W/kg BM for 10 minutes. SC was accomplished by wearing a neoprene-covered silicone cooling cap (Paxman, Huddersfield, UK) connected to a cooling machine (Paxman cooler PScalpC-1, Paxman, Huddersfield, UK) for 30 minutes. Temperature of the coolant was–9°C to –10°C.

Protocol

Each session started in a 22°C climatic chamber (Weiss Enet, Tiel, The Netherlands) with 20-minute habituation, followed by baseline measurements and the intervention protocol. Subsequently, during a 5-minute break, subjects were transferred to an adjacent 30°C, 50% relative humidity climatic chamber. This was followed by a short final preparation period of 3-minute cycling at 120 W. Hereafter, subjects performed the 15-km TT on a cycle ergometer (Lode, Groningen, The Netherlands). During the trial subjects were blind to performance measures but were informed of completed distance each kilometer. The 4 TTs were allocated in balanced order and at least 3 days apart.

Measurements

During the TTs, power output (PO) was recorded every second. Rectal temperature (T_{re}) was measured every second using a rectal thermistor (Yellow Springs Instruments 700 series, Yellow Springs, OH, USA) inserted 10 cm beyond the anal sphincter. A weighted average of 8 iButtons (DS1922L, Maxim Integrated Products Inc, Sunnyvale, CA, USA) resulted in 10-second values for mean skin temperature (T_{sk}), as described by ISO9886.[16] Heart rate was recorded at 5-second intervals (Polar Electro, Finland). For the TT, data were reduced to 1-km values.

Thermal sensation (TS) and thermal comfort (TC) were measured every 5 km on a 9-point and 5-point scale, respectively.[17] RPE was measured every kilometer on a 20-point scale.[18]

Statistics

Experimental condition was the independent variable, whereas PO, T_{re}, T_{sk}, heart rate, RPE, TS, and TC were the dependent variables. Significance of effects over time was determined using 2-way ANOVAs for repeated measurements with Bonferroni correction (SPSS 17.0, SPSS Inc, Chicago, IL, USA). One-way ANOVAs were used to determine the significance of effects of the experimental conditions at separate kilometers, as well as on finish times and average PO. Statistical significance was set at the 5% level. Values are reported as mean ± SD.

Results

Effect of Preparation Regimens

In Figure 1, T_{re} and T_{sk} before and during the TT are shown. Before the start of the intervention, T_{re} and T_{sk} were similar. Ice-slurry ingestion resulted in a cooler core at the start of the TT than performing a warm-up ($P < .05$). There was a trend that T_{re} was more reduced in SC+ICE than in ICE ($P = .06$). At the start of the TT, both T_{sk} and TS were lower for SC+ICE than for the other conditions ($P < .05$). TC was similar.

Time-Trial Performance

In Figure 2a, the average PO per kilometer of the TT is shown. There was no overall effect between conditions on PO and finish time. However, during kilometers 13 and 14, PO for SC+ICE (231 ± 23 and 239 ± 24 W, respectively) was significantly higher than for WARM-UP (214 ± 28, $P = .01$, and 219 ± 27 W, $P = .02$, respectively). In addition PO for ICE (230 ± 32 W) was higher than for WARM-UP during kilometer 13 ($P = .03$).

Physiological and Perceptual Responses

Differences in T_{re} and T_{sk} between the ice-slurry and warming-up conditions were observed during the first half of the trial ($P < .05$). Overall, T_{sk} was significantly lower for SC+ICE than for WARM-UP ($P = .02$). Heart rate for WARM-UP was higher than for SC+ICE and ICE during the initial stages of the trial, but no differences were found after 3 km.

No overall effect for RPE was observed, but at separate kilometers in the final stages of the TT, some RPE scores deviated (Figure 2b). No effects for TS and TC were observed during the trial.

Discussion

This study showed that the lower the body temperature and sensation of coolness at the start of the TT, the more beneficial it was for the pacing profile at the final stages. This finding agrees with previous precooling experiments on longer cycling trials (40–90 min), showing physi-

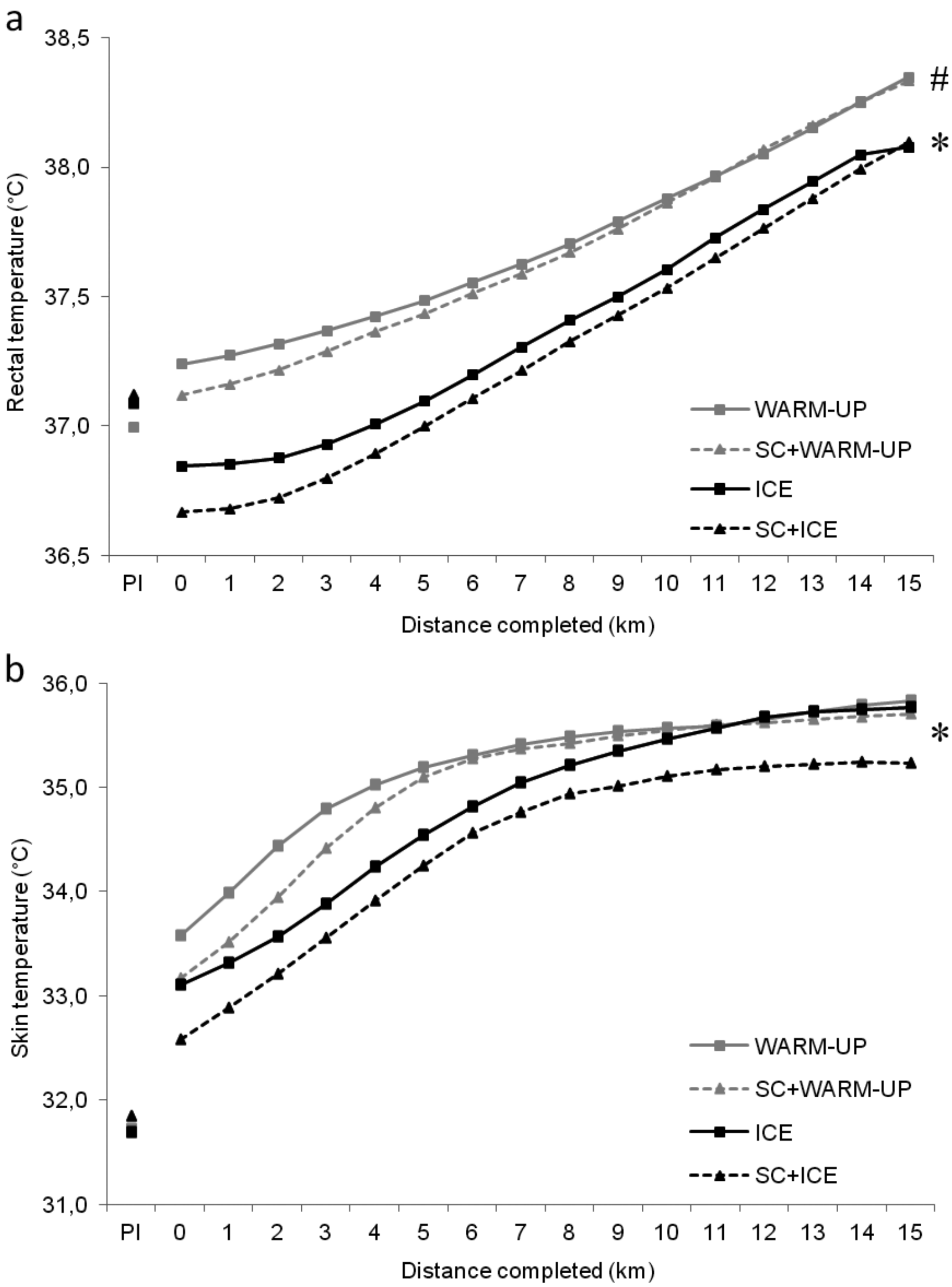

Figure 1 — (a) Rectal and (b) skin temperature preintervention (PI), at the start of the time trial (km 0) and averaged per kilometer of the time trial. *Significant difference between scalp cooling (SC) + warm-up and SC + ice-slurry ingestion (ICE) ($P < .05$). #Significant difference between SC+WARM-UP and ICE ($P < .05$). For clarity of the figure, no error bars are displayed.

ological differences in the first part of the trial and pacing adjustments at the final stages.[7,8] However, we did not find an overall effect on performance, which is in contrast to the referenced studies. Although direct comparison is difficult due to methodological differences, it appears that exercise duration is important for obtaining overall performance benefits from precooling. Nevertheless, a higher work rate near the finish as a result of precooling may still be beneficial during tactical races.

Precooling the core with ice-slurry ingestion appeared to be more effective in accomplishing pacing benefits than precooling the scalp. Scalp precooling led to a marginal decrease in thermal strain and a slightly cooler sensation at the start of the TT, but pacing and performance benefits

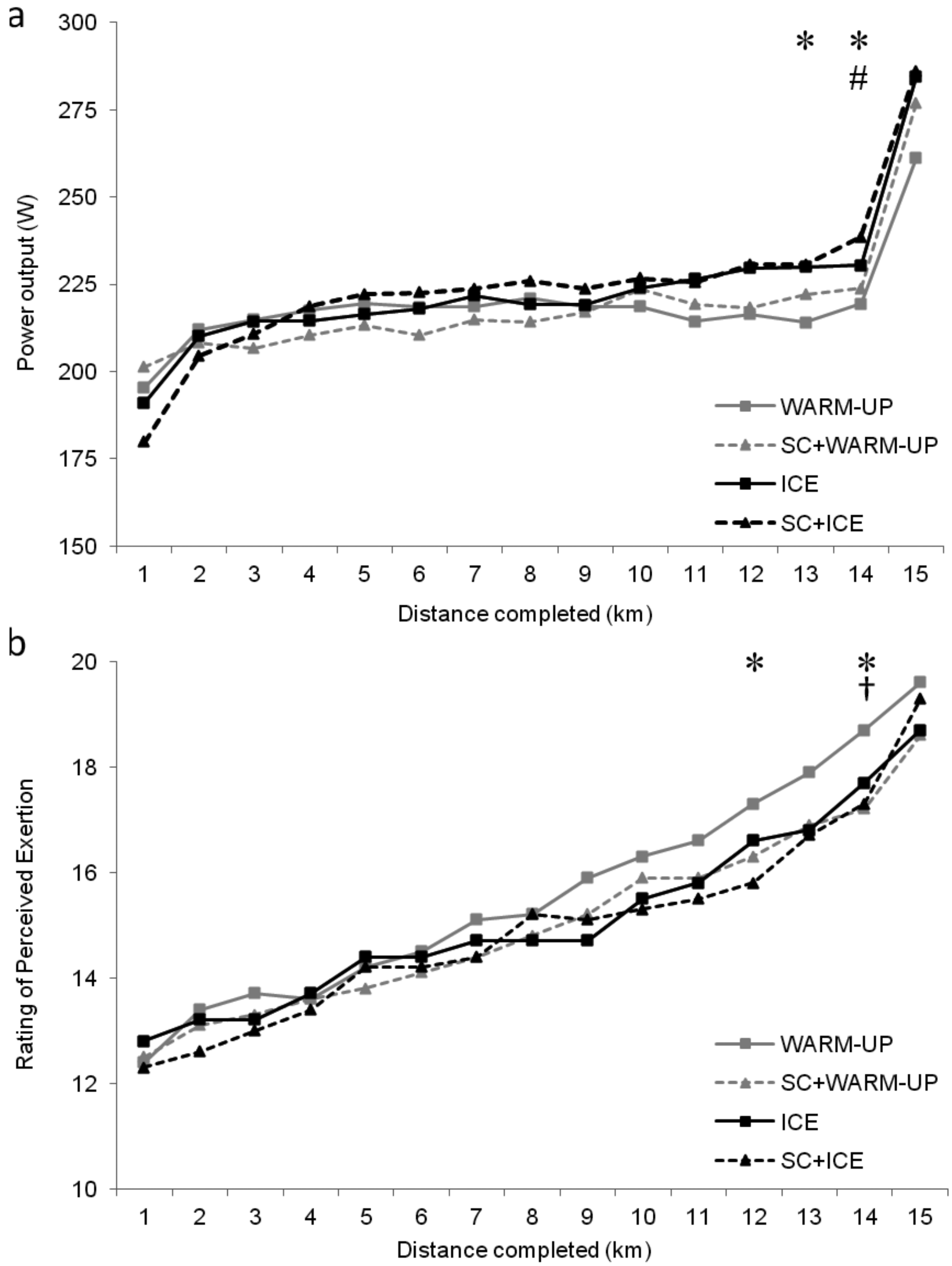

Figure 2 — (a) Power output and (b) rating of perceived exertion during the time trial. *Significant difference between warm-up and scalp cooling (SC) + ice-slurry ingestion (ICE) ($P < .05$). #Significant difference between warm-up and ICE ($P < .05$). †Significant difference between warm-up and SC+ICE ($P < .05$). For clarity of the figure, no error bars are displayed.

during the trial were negligible. The limited physiological effects of scalp cooling may be due to the insulative capacity of the skull[19] and the small cooling area. The absence of a perceptual effect on performance confirms the results of Barwood et al,[20] who found no effect of thermal perception on the anticipatory selection of PO.

RPE differed during the final stages of the TT. The higher RPE for WARM-UP was accompanied by a significantly lower PO than with SC+ICE. This finding seems to disagree with the concept that athletes maintain a similar RPE template across conditions of similar duration and adjust their work rate accordingly.[21]

Carbohydrate ingestion via syrup might be considered a confounding factor. However, it is unlikely that the ingestion of only 6 g carbohydrates 20 minutes before medium-duration aerobic exercise (<45 min) improves performance in the final stages by extending body glycogen content[22] or by nonmetabolic pathways.[23]

In conclusion, the preparation regimen providing the lowest body-heat content and sensation of coolness at the start of the TT (ICE+SCALP) appeared to be most beneficial for pacing in the latter stages. However, overall performance was not significantly improved after precooling, possibly because of the limited trial length.

Acknowledgments

Authors Levels and Teunissen contributed equally to this article.

References

1. Gray S, Nimmo M. Effects of active, passive or no warm-up on metabolism and performance during high-intensity exercise. *J Sports Sci*. 2001;19:693–700. PubMed doi:10.1080/02640410152475829
2. Hajoglou A, Foster C, De Koning JJ, Lucia A, Kernozek TW, Porcari JP. Effect of warm-up on cycle time trial performance. *Med Sci Sports Exerc*. 2005;37:1608–1614. PubMed doi:10.1249/01.mss.0000177589.02381.0a
3. Proske U, Morgan DL, Gregory JE. Thixotropy in skeletal muscle and in muscle spindles: a review. *Prog Neurobiol*. 1993;41:705–721. PubMed doi:10.1016/0301-0082(93)90032-N
4. Ross A, Leveritt M, Riek S. Neural influences on sprint running: training adaptations and acute responses. *Sports Med*. 2001;31:409–425. PubMed doi:10.2165/00007256-200131060-00002
5. Gonzalez-Alonso J, Teller C, Andersen SL, Jensen FB, Hyldig T, Nielsen B. Influence of body temperature on the development of fatigue during prolonged exercise in the heat. *J Appl Physiol*. 1999;86:1032–1039. PubMed
6. Uckert S, Joch W. Effects of warm-up and precooling on endurance performance in the heat. *Br J Sports Med*. 2007;41:380–384. PubMed doi:10.1136/bjsm.2006.032292
7. Duffield R, Green R, Castle P, Maxwell N. Precooling can prevent the reduction of self-paced exercise intensity in the heat. *Med Sci Sports Exerc*. 2010;42:577–584. PubMed
8. Ihsan M, Landers G, Brearley M, Peeling P. Beneficial effects of ice ingestion as a precooling strategy on 40-km cycling time-trial performance. *Int J Sports Physiol Perform*. 2010;5:140–151. PubMed
9. Ross ML, Garvican LA, Jeacocke NA, et al. Novel precooling strategy enhances time trial cycling in the heat. *Med Sci Sports Exerc*. 2011;43(1):123–133. PubMed doi:10.1249/MSS.0b013e3181e93210
10. Siegel R, Mate J, Brealey MB, Watson G, Nosaka K, Laursen PB. Ice slurry ingestion increases core temperature capacity and running time in the heat. *Med Sci Sports Exerc*. 2010;42:717–725. PubMed
11. Nybo L, Nielsen B. Hyperthermia and central fatigue during prolonged exercise in humans. *J Appl Physiol*. 2001;91:1055–1060. PubMed
12. Schlader ZJ, Simmons SE, Stannard SR, Mundel T. The independent roles of temperature and thermal perception in the control of human thermoregulatory behavior. *Physiol Behav*. 2011;103:217–224. PubMed doi:10.1016/j.physbeh.2011.02.002
13. Tikuisis P, Meunier P, Jubenville CE. Human body surface area: measurement and prediction using three dimensional body scans. *Eur J Appl Physiol*. 2001;85:264–271. PubMed doi:10.1007/s004210100484
14. Ansley L, Marvin G, Sharma A, Kendall MJ, Jones DA, Bridge MW. The effects of head cooling on endurance and neuroendocrine responses to exercise in warm conditions. *Physiol Res*. 2008;57:863–872. PubMed
15. Ely BR, Cheuvront SN, Kenefick RW, Sawka MN. Aerobic performance is degraded, despite modest hyperthermia, in hot environments. *Med Sci Sports Exerc*. 2010;42:135–141. PubMed
16. International Standardization Organization. *Ergonomics—Evaluation of Thermal Strain by Physiological Measurements*. Geneva. Switzerland: International Standardization Organization; 2004.
17. Gagge AP, Stolwijk JA, Hardy JD. Comfort and thermal sensations and associated physiological responses at various ambient temperatures. *Environ Res*. 1967;1:1–20. PubMed doi:10.1016/0013-9351(67)90002-3
18. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc*. 1982;14:377–381. PubMed
19. Xu X, Tikuisis P, Giesbrecht G. A mathematical model for human brain cooling during cold-water near-drowning. *J Appl Physiol*. 1999;86:265–272. PubMed
20. Barwood MJ, Corbett J, White D, James J. Early change in thermal perception is not a driver of anticipatory exercise pacing in the heat [online publication ahead of print, December 5, 2011]. *Br J Sports Med.* doi:10.1136/bjsports-2011-090536.
21. Tucker R, Noakes TD. The physiological regulation of pacing strategy during exercise: a critical review. *Br J Sports Med*. 2009;43:e1. PubMed doi:10.1136/bjsm.2009.057562
22. Burke LM, Hawley JA, Wong SH, Jeukendrup AE. Carbohydrates for training and competition. *J Sports Sci*. 2011;29(Suppl 1):S17–S27. PubMed doi:10.1080/02640414.2011.585473
23. Rollo I, Williams C. Effect of mouth-rinsing carbohydrate solutions on endurance performance. *Sports Med*. 2011;41:449–461. PubMed doi:10.2165/11588730-000000000-00000